Analysis of thinning programs application in the Leningrad region

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Supervisors: Per Magnus Ekö, Alexander Alekseev

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Master Thesis no. 145
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CONTENTS

Abstract

This paper aims at investigating a possible applicability of a Swedish forest growth simulator “ProdMod” in conditions of North-West Russia. The result from ProdMod was based on materials from The Series of Stationary Experimental Objects and particularly section 1 “Development of Stands Not Touched By Silvicultural Activity”.

Results of forecast by ProdMod are compared with stands development observed on sample plots. Basal area and volume development are two crucial parameters in the comparisons. ProdMod shows quite good results, but there are some dissimilarities in volume development. It is concluded that this program can be useful in conditions of North-West Russia, but still it requires some corrections.

Possible successful thinning programs (from economic point of view) are evaluated. The 6 thinning programs with different intensities and frequencies of thinning were investigated in stands with different tree species composition. The program with “flexible” thinning schedule for each stand shows the highest results incase of NPV. There isn’t a universal program, which shows only highest results for all parameters. Each program has its strong and weak sides. Despite good results, some of successful thinning programs can hardly be applied in North-West Russia due to the features of Russian forest sector and thinning rules.

Key words: *ProdMod, applicability, North-West Russia, comparison, thinning program, successful, flexible*

Introduction

The goal of forestry varies between countries. In some countries economy is focused (Sweden, Finland), in other countries foresters put more emphases on other functions of forest (Poland, Germany). The different paradigms are often connected to the ownership, historical traditions of silvicultural practice, population density, size of forest area, importance of the forest sector for national economy etc. Nowadays Russia belongs to an intermediate group of countries with an ongoing change of the economical system.

Main Actors of Russian Forestry.

After the chain of reforms in Russia the government wants to increase probability of forestry, since the state forest enterprises has historically not covered their expenses (new Forest Act 2006). All forests in Russia are owned by state, but private forest logging companies can rent a forest land for different purposes. According to Federal Forest Agency 122,2 million hectares of forest are rented on 1st December 2007. Now at least forestry needs to be self sufficient or possible give income to the state. Today Federal Forest Agency transfer responsibility for forest regeneration, pre-commercial thinning, fire protection and other forestry operations to private forest logging companies, who rent the forest. The state forest enterprises should control their actions and manage forest operations in non-rented forests. As a result added duties will significantly increase expenses of private forest companies. Permission for providing thinning operations is a way to compensate growing expenses.

Previous researches.

There are lots of articles and research about efficiency of both pre-commercial and commercial thinning in Russia and in the former USSR (Melekhov I.S., 2007, Sennov S.N. 2005), but during period of planned economy forest researchers did not pay much attention to economic outcome of thinning.

Features of Russian Forestry.

There are a several circumstances in Russian forestry, which influence silvicultural measures, such as thinning:

1. General insufficient usage of forest recourses;
2. Illegal logging. According to the official statistic of Federal Forest Agency in period from 1.01.2007 to 31.06.2007 in North-West Russia: 1747 cases of illegal logging were noticed, more than 100 thousands m^3 were cutted illegally and only in 17,3% cases authorities were able to press charges against company;
3. Huge losses due to the fires, insects and deceases. In year 2006 4400 hectares of forest were damaged by fires, 4000 ha by different diseases and 900 ha were damaged by insects (FFA 2006);
4. Not-well developed forest infrastructure

Under these prerequisites Russian forest logging companies should adapt thinning practices (intensity, frequency) to get maximum economic efficiency. Today economical efficiency is in focus, as there is a need to cover increasing expenses for salaries and costs for forest operations. The change is of course in accordance with the transition from planned economy to market economy - increasing expenses and an unstable market situation.

Importance of thinning in Russia.

Logging companies are interested in making their work more efficient, so they would like to know more about effects of different thinning programs. This is a hot issue especially in the North-West of Russia where forest the sector is well developed. Russia has 82 billion m^3 of standing volume and forest covers 45% of land area (FFA 2008). According to the data from the government of the Leningrad region 2005 the harvests in the rented forest amounted to 65% of the total harvested volume in the region. The Federal Forest Agency reports that in year 2006 in the Leningrad region approximately 4 million m^3 of timber were harvested in final fellings and approximately 0.6 million m^3 in thinning operations.

Aim and rules of thinning in Russia.

According to the thinning legislation the main aim of thinning in Russia is to promote a valuable stand by the time of final felling. Intensity of thinning depends from forest's prescription (exploitation, protection or reserved), forest type, tree species composition, age, site index, condition of stand. According to the Thinning Rules (2007) intensity of commercial thinning depends from index of related basal area of particular stand. The thinning removal varies from less than10% up to 50% of the volume. Specialists of North-West Forest Inventory Enterprise noted that 20-25% is a usual rate of thinning intensity.

New view of thinning in Russia.

Thinning schedules developed by Saint-Petersburg Forest Research Institute and team of Pskov Model Forest Project suggest more intensive thinning (Romanyuk B. at al, 2005). According to analyses of the outlined thinning programs, they should be self sufficient or give small income.

Different tools decision support.

There are different tools that could be used to develop and analyze thinning programs. Some of them have a long history – yield tables, long term field research. Other tools are designed in the recent time – thinning schedules (guides). One of the most recent tools are different kinds of computer programs: GIS programs (MapInfo, ArcView, etc), forest growth simulators (ProdMod, Forest Time Mashine etc.) (Andersson et al. 2005, Ekö 1985) and others. Different computer programs simplify analyses and comparisons of data, furthermore they show results in an obvious way that helps to make decisions. In this investigation it will be studied if a Swedish forest growth simulator (ProdMod) could be applied for Russian conditions.

Topics of the current investigation.

Lots of the questions appear when studying the economical efficiency of thinning programs: Can Swedish forest growth simulator work in conditions of North-Western Russia? What measures are necessary for adaptation to these conditions? Are actual thinning programs enough profitable? What thinning program is economically efficient? Does a universal profitable thinning program exist? What factors affect a success of thinning programs? Trying to find answers to these questions is an interesting challenge.

The aim of this paper is to find profitable thinning programs for different forest stands types, using computer technologies and European experience, taking into consideration conditions in the Russian forest sector.

Materials and methods

This study consists from two parts: Part 1 Verification of ProdMod's applicability in Russia and Part 2 Comparison of thinning programs. A Swedish computer based growth simulator "ProdMod" was used to forecast development of forest stands in this study. The simulator has been shown to work well for Swedish conditions. In this study it was tested for conditions of North-West Russia. If it can be shown to work well also in this area it will be used to compare different thinning programs. A main criterion for the evaluation of different thinning programs in this study is NPV (net present value). Cost and incomes connected to the different thinning programs are assessed according to Russian standards. Comparison of different thinning programs will also be made using cost and incomes according to Swedish standards.

Part 1. Verification of ProdMod's applicability in Russia

About ProdMod

ProdMod, which is a simulation program, was used for estimation of growth and yield. The simulator was developed in Sweden (Ekö 1985) and is based on data from 17500 plots from the Swedish National Forest Survey. The simulator is a stand growth model, where the growth object is the stand basal area. Forecasts can be made for monocultures as well as for mixtures of spruce, pine, birch, beech and oak (other broadleaves are treated unspecified as a separate group.) The growth simulator has been widely used in various tools for planning in Sweden, where ProdMod is one of the applications (software).

Required input data on the stand are: basal area, number of stems per ha and age at breast height. These variables must be specified for all present species in the stand. For simulation the user must also specify the position of the stand in Sweden (latitude, altitude and climate zone). Other site variables are site index, field vegetation type and soil moisture. The growth simulator is applicable if the top height of the stand is more than 8 m, corresponding to a stand age of app. 15-20 years. The output from the simulator is made for 5 year periods, displaying data before and after thinning/natural mortality. The stand description is divided for each tree species in terms of age, top height, no of stems, basal are, diameter, volume, annual increment of volume, and biomass of different fractions of the stand.

Thinning is controlled by the user and has two parameters: removal of basal area and number of stems. Thus it is possible to make experiments in ProdMod with different thinning programs (intensity, frequency and form). In Russia the intensity of thinning is defined by the percentage of removed volume, but in ProdMod it is only possible to specify the removal of basal area.

Data to check applicability of ProdMod in Russia

Two alternatives to verify the applicability of ProdMod for conditions of Northern-West Russia were indentified:

1. Comparison with yield tables for North-West of Russia by Zagreev V.V. (1978)
2. Comparison with published data by Saint Petersburg Forestry Research Institute: The Series of Stationary Experimental Objects; section 1 “Development of Stands Not Touched by Silvicultural Activities”.

The yield tables by Zagreev don’t include some initial data, which are needed for the simulations. The tables are not differentiated according to vegetation type, soil moisture etc. Due to these facts the yield tables were ruled out as a comparison.

To check whether Prod Mod works in conditions of North-Western Russia data from publications of Saint Petersburg Forestry Research Institute was used instead. Data from stands development in the Series of Stationary Experimental Objects, were used. In particularly section 1 “Development of Stands Not Touched By Silvicultural Activity” was used for the study. Data set contains long series of historical data containing all necessary parameters for the simulations. Unfortunately, data concerning thinned stands has not yet been published.

All observations and records were done with supervision of two researchers - Filipov G.V. and Pirogov N. A. Due to this fact the data seems to be reliable and mistakes should be rare.

The climatic and geographical positions of Sweden are similar to North-Western Russia, so growth conditions should be rather equal. The experimental objects (sample plots) are located in the experimental forest “Siverskiy les” (Figure 1). This forest unit is an experimental site belonging to the Forest Research Institute since 1927.

Figure 1 Location of experimental forest “Siverskiy les”.

Sample plots were established in 1958-1970 in stands with different forest types, age and tree species compositions. There are data from 47 sample plots described in the paper (Filipov G.V. 2001). Usually plots have a rectangular shape and are located in the center of a forest stand. The size of plots varies from 0,1 to 1,06 ha. There is a buffer zone of 20 m width surrounding each plot. The locations of plots are permanently marked and all trees are numbered and marked by painting.

The interval of revision is 5-8 years. On each revision complete data collection was made including measurements of height, diameter and judgment of status (healthy, damaged, dead). All documents of revisions and materials are available in Saint Petersburg Forestry Research Institute, in the laboratory of Forest Inventory and Mathematic Methods in Forestry.

The paper (Development of Stands Not Touched By Silvicultural Activity, SPb FRI) contains maps and tables with information about stands (age of stand, basal area, diameter, volume, volume of natural mortality, number of stems). Table 1 and Figure 2 show as an example data about plot 1.

Table 1. Data from sample plot 1 in Orlovskoe forest district in the forest compartment № 106. In this table P stands for pine, S for spruce, B for birch, As for aspen, and Ald for alder.

Tree species composition, %	Summary for all species			Data for individual species						
	Average height, m	Basal area, m2/ha	Volume, m3/ha	Age, age	Average height, m	Mean diameter, cm	Number of stems, st/ha	Basal area, m2/ha	Volume, m3/ha	Volume of dead wood m3/ha
77S	13,8	26,2	198,9	50	13,1	11,8	1878	20,5	153,0	0
3P				50	16,1	14,1	38	0,6	5,1	0
14B				50	15,3	11,0	388	3,7	28,7	0
5As				50	17,5	11,9	95	1,1	9,4	0
1Ald				50	17,9	12,3	25	0,3	2,6	0
78S	15,0	31,1	258,4	55	14,6	12,8	1904	24,4	201,9	2,1
3P				55	17,3	15,9	38	0,8	6,9	0
14B				55	16,1	11,9	388	4,3	35,4	0,2
4As				55	17,7	13,7	89	1,3	11,2	0
1Ald				55	17,6	13,4	25	0,3	3,0	0
77S	18,2	35,0	346,0	62	17,7	14,3	1687	27,1	267,3	14,0
3P				62	18,4	18,0	38	1,0	9,1	0
14B				62	19,2	13,4	337	4,8	47,3	1,9
5As				62	22,4	17,5	76	1,8	19,3	0,4
1Ald				62	17,6	13,4	25	0,3	3,0	0
78S	19,3	33,2	338,3	69	19,1	15,9	1273	25,1	263,8	29,9
3P				69	19,5	20,3	31	1,0	9,5	0,4
12B				69	19,0	16,0	216	4,4	40,1	4,0
7As				69	22,4	20,9	76	2,7	24,9	0
77S	21,8	31,6	364,2	74	21,5	17,0	1050	23,8	280,1	20,7
2P				74	19,0	19,3	25	0,8	7,1	0
13B				74	22,1	18,6	165	4,5	48,2	1,7
8As				74	24,7	22,5	63	2,5	28,8	2,1
73S	23,2	34,2	411,3	80	22,4	18,9	891	25,0	301,9	15,5
3P				80	22,9	23,6	25	1,1	11,9	1,2
14B				80	25,3	20,8	133	4,6	55,3	1,9
10As				80	25,9	26,7	63	3,5	42,2	0

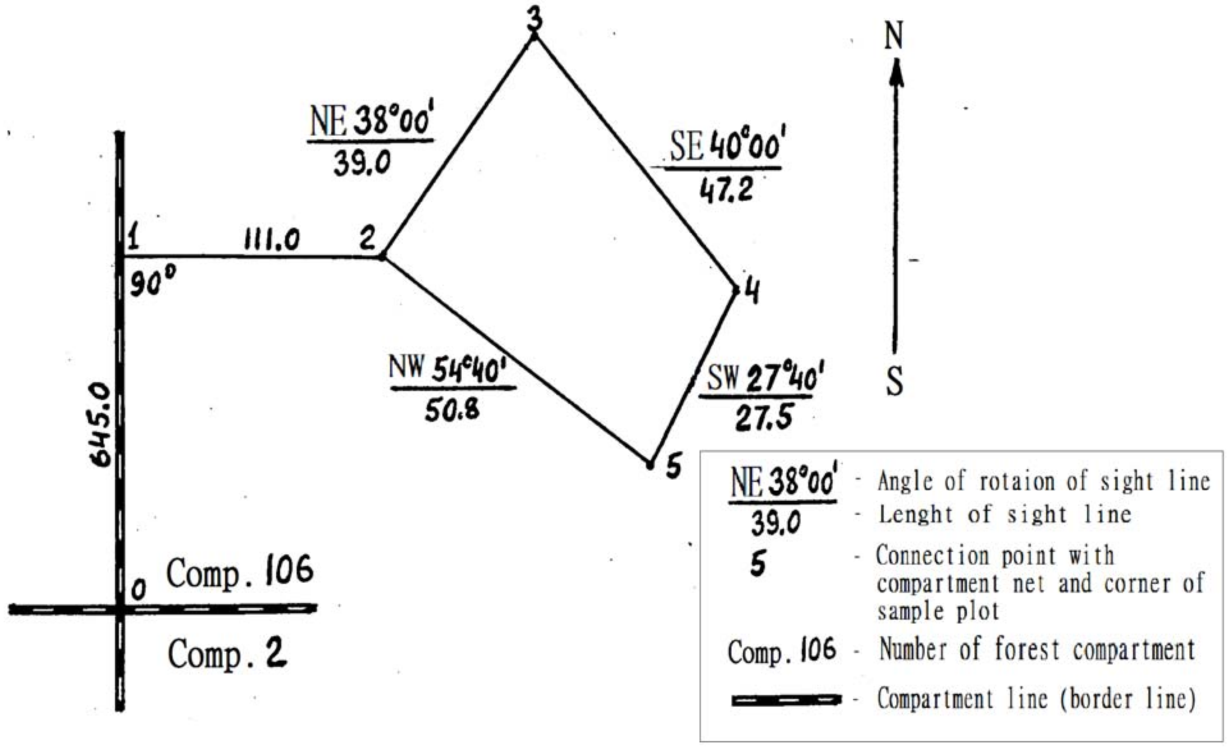

Figure 2. Sketch of sample plot 1 in Orlovskoe forest district in forest compartment № 106. Length of sight line is in meters.

The aim of the establishment of the sample was to create a data bank for research about different aspects of forestry. Generally it concerns investigation of growth rate, mortality and natural regeneration in different age periods and in different forest stands. The purpose of publishing the data is to make it accessible to those whom it could be interesting for and to not allow loss of this information due to unforeseen circumstances.

Verification of ProdMod

For the verification of ProdMod data from 10 plots № 1, 2, 3, 5, 7, 9, 10, 12, 20a, 20b were used. The plots were chosen randomly from 47 available plots. To check ProdMod the development on the plots were simulated with starting point from the initial data of the plots. Simulations were made for periods corresponding to the observed periods in the data. Data about initial parameters of the study stands are present in Table 2.

Table 2. Initial data concerning plots № 1, 2, 3, 5, 7, 9, 10, 12, 20a, 20b.
(P stands for pine, S for spruce, B for birch, As for aspen, and Ald for alder)

№ of stand	Tree species composition, %	Summary for all species				
		Average height, m	Basal area, m2/ha	Volume, m3/ha	Number of stems, st/ha	Stand age, years
1	**77**S **3**P **14**B **5**As **1**Ald	13,8	26,2	198,9	2424	50
2	**70**S **18**B **12**As + P	18,2	33,5	320,4	1588	63
3	**62**S **19**As **15**B **3**P **1**Ald	22,9	30,5	353,9	921	80
5	**56**S **28**B **13**As **3**P	21,7	34,1	377,9	1127	75
7	**71**S **22**B **6**P **1**As	19,5	32,2	333,8	1580	65
9	**68**P **28**S **2**B **2**As	15,1	24,9	199,7	1640	55
10	**75**P **11**B **7**S **7**As	25,9	34,9	415	865	95
12	**83**P **6**S **6**B **5**As	23,9	33,8	368,7	975	75
20a	**45**P **33**S **14**B **8**As	15,3	26,4	215	2155	34
20b	**52**P **31**S **15**B **2**As	14,6	26,5	207,4	2325	34

The next step was to compare estimated and observed volume and basal area development. Graphs were drawn to make visual comparisons.

Part 2. Comparison of thinning programs

Comparison of thinning programs

Four alternative thinning programs were compared (Table 3).

Table 3. Thinning programs used in simulation.

Thinning program	Removal basal area, %	Number of thinning
No thinning	No	
1-70	70	1
2-45	45	2
3-30	30	3
4-25	25	4
Synthesis	Varies for each tree species and mixture	

Many forest stands in Russia has not been touched by silvicultural activity. There weren't made any thinnings at all (neither precommercial nor commercial). So **No thinning** is the standard option and the results are interesting for comparison with the simulated active thinning programs.

In comparison with European countries Russia has the biggest wooded area in the world and a rather low population density. So for providing silvicultural treatments in all stands which allow thinnings the thinning program **1:70** could be an option– one heavy thinning and after that final felling. In this case the remaining 30% o the stand should make up to about 700 trees per ha in the final felling.

According to the Russian rules of Thinning forest user can provide usually only two commercial thinnings before final felling, so thinning program **2:45** became a second alternative.

In the Leningrad region forest districts forest logging companies start to pay more attention to thinning due to prohibition of clear cuttings (only sanitary cuttings are allowed). In this case the thinning program **3:30** is one alternative that could be interesting in regard of the restriction of final felling.

In countries with intensive forest management the thinning program **4:25** is typical program. This program is tested for Northern-West Russia, to evaluate the efficiency (economical and silvicultural) in comparison with other programs.

The last thinning program is called **Synthesis** and is a combination of different thinning intensities and intervals between thinnings. The combination is a priori supposed to be suitable from an economical point of view, assuming Russian conditions. All programs above are quite extreme in comparison with the Synthesis program. The Synthesis program varies for each species due to the different rotation age, costs, revenues and silvicultural aspects.

As initial data for the simulations should be typical for North West of Russia tree species compositions were set to pure spruce, pine, and birch forests: mixed forests with 50% spruce – 50% birch, 50% pine – 50% birch.

The simulations were set to start after pre-commercial thinnings, since ProdMod is not applicable at an earlier stage.

Initial stand parameters:

1. Stand age – 40 years for pine and spruce, 30 years for birch (ProdMod works if the top height of stand is more than 8 m, it corresponds to 35-40 years old stands for pine and spruce and to 30 years for birch in the current data set);
2. Total number of stems was set to 3000 st/ha (number of stems after pre-commercial thinning);
3. Site Index was specified as constant for all stands and was for spruce and pine set to 22m, for birch SI it was set to 21m (these numbers relate to the average yield class in North West of Russia. According to the yield tables in this yield class the stand will reach 21 m height in 100 years for spruce and pine and 20m for birch);
4. Initial basal area was set to 23 m^2/ha (this value was chosen corresponding to average diameter of 10 cm according to the yield tables for the chosen site indexes);
5. The latitude was set to 60 degrees and height above sea level was set to 14 meters (Stockholm and St Petersburg);

6. Blueberry – was chosen as field vegetation type;
7. The thinning form was set to intermediate (it means that percentage of removed basal area and stems was the same. In the first thinning the harvest included wolf trees, damaged trees and depressed trees; it will help to pay at least for logging costs and to avoid degradation of forest);
8. Rotation age for pine and spruce was set to 100 years, for birch 80 years;
9. All thinning should be provided according to schedules in Table 4:

Table 4. Thinning schedules applied in simulations.

1. Thinning schedule for pure stands of pine and spruce.

Age	**Thinning program**			
	1:70	*2:45*	*3:30*	*4:25*
50	X	X	X	X
60				X
65			X	
70				X
80		X	X	X
X - age of thinning				

2. Thinning schedule for pure stands of birch

Age	**Thinning program**			
	1:70	*2:45*	*3:30*	*4:25*
40	X	X	X	X
50				X
55			X	
60				X
70		X	X	X
X - age of thinning				

3. Thinning schedule for mixed stands

Age	**Thinning program**			
	1:70	*2:45*	*3:30*	*4:25*
50	X	X	X	X
60				X
65			X+X/2	
70				X+X/2
80	FFB	X/2 +FFB	X/2 +FFB	X/2 +FFB
X - age of thinning				
FFB- final felling of birch				

X/2 – mean that intensity of thinning of coniferous is reduced twice, because of final felling of birch (FFB).

4. Intensities of thinning program *Synthesis* for different stands

Age	Stand				
	Pure Spruce	Pure Pine	Pure Birch	Mix Stand	
				Spruce/Pine	Birch
40			25		
50	40	25			30
55			40		
65	35	35		30	45
70			40		
80	30	35	FFB	30	FFB

The volume derived from thinnings and the final cutting was compared as well as the species distribution and mean diameters.

Economical evaluation of thinning programs

Thinning programs and their outcomes are evaluated considering costs of operations and revenues from harvests. Possible revenues and costs were taken from the forest logging company “INROST” – a typical representative of forest logging companies in North-West of Russia, which is oriented toward export of round-wood to Finland.

Prices and costs for the forest operations are from INROST bookkeeping department. Prices (Table 5) were taken from contracts with Finnish partners; contract type is FCA, it assumes that the seller fulfils his obligation to deliver timber, cleared for export, into the charge of the buyer at the named place or point, in case of INROST it is theirs warehouse. When the seller assistance is required in making the contract with the carrier (trucks) the seller may act at the buyer's risk and expense.

Cost for the harvesting was taken from contracts with Finish companies which provided this service for INROST. Cost for the transportation to warehouses was calculated as the sum of payments for loading in the logging area, sorting, transportation and unloading in warehouse. All this data are shown in Table 6.

Before harvesting forest logging company must pay a stumpage price (Table 7) which is a governmental fee for logging. It differs among tree species, size of assortment (big, medium, small) and quality (commercial timber or firewood).

The size of different assortments is defined by diameter of the top of the log: small – diameter less than 13 cm, medium – between13 and 25 cm, large – diameter more than 25 cm. These fees in table 7 are set for final cuttings. For thinnings fees are reduced by 50%.

Table 5. Prices of timber per m^3.

Assortment	**Price, €**
Saw log spruce	53
Saw log pine	51
Pulp wood spruce	31
Pulp wood pine	26
Pulp wood birch	30
Pulp wood aspen	22

Table 6. Costs for forest operations.

Operation	**Cost, €**
Harvesting	11 per m^3
Transporting to warehouse	4 per m^3

Table 7. Stumpage price per m^3 in final felling set by governmental regulation № 310, May 22, 2007.

Species	**Price for assortment of roundwood, €**			
	Big (>25 cm)	**Medium(<25cm)**	**Small (<13cm)**	**Firewood**
Pine	7.32	5.22	2.62	0.21
Spruce	6.59	4.69	2.36	0.19
Birch	3.66	2.63	1.33	0.23
Alder	2.19	1.57	0.79	0.18
Aspen	0.70	0.53	0.29	0.10

As a conclusion forest companies get income from sale of timber and pay for harvesting, transportation to the ware house and stumpage price.

Economical outcomes in terms of NPV (net present value) from different thinning programs were calculated as:

$$NPV = \frac{R_1}{(1+r)^1} + \frac{R_2}{(1+r)^2} + ... + \frac{R_n}{(1+r)^n} - \frac{C_1}{(1+r)^1} - \frac{C_2}{(1+r)^2} - ... - \frac{C_n}{(1+r)^n}$$,where

R – revenue from logging, €;
C – costs, €;
r – interest rate (2% was chosen, because of big losses due to the road construction and moving to intensive management);
n – year.

In first thinnings the volume of wood which can be sold is reduced by 50% because of small log diameters and a big amount of waste. However stumpage price is paid for the total volume.

The Net Present Value from different thinning programs was calculated and the results compared.

Estimation of NPV for Swedish conditions and comparison of NPV results between Sweden and Russia

Estimation of NPV for Swedish conditions was made by software developed by the Southern Swedish Forest Research Centre “Assessment of net values” (Ekö pers. com.) It is based on statistical data from different sources among them the Swedish forest owner association. This program has been shown to work well in Sweden. But data are available only for spruce and birch stands; therefore no calculations have been made for pine stands.

The required input data are harvested volume, average diameter weighted by basal area and number of stems. Furthermore it is necessary to specify minimum dimension for pulpwood and sawn timber, as well as assumed quality distribution among sawn assortments. This data from different thinning programs was used from simulations above.

The program calculates a solid cubic meters on and under bark, average stem volume, harvest cost and income, net income and some statistics (harvested cost per m^3,income per m^3 etc.) It shows also a graph with price for harvesting of one m^3 according to average stem volume.

Results

Results of verification of ProdMod's applicability in the Leningrad region

Comparison of data from the paper "Development of Stands Not Touched By Silvicultural Activity" (here regarded as "real" data) and simulations with ProdMod gave the results shown in Figure 3 to 6.

Basal area development.

On some plots the results of simulation of basal area were quite close to the empirical data (Figure 3).

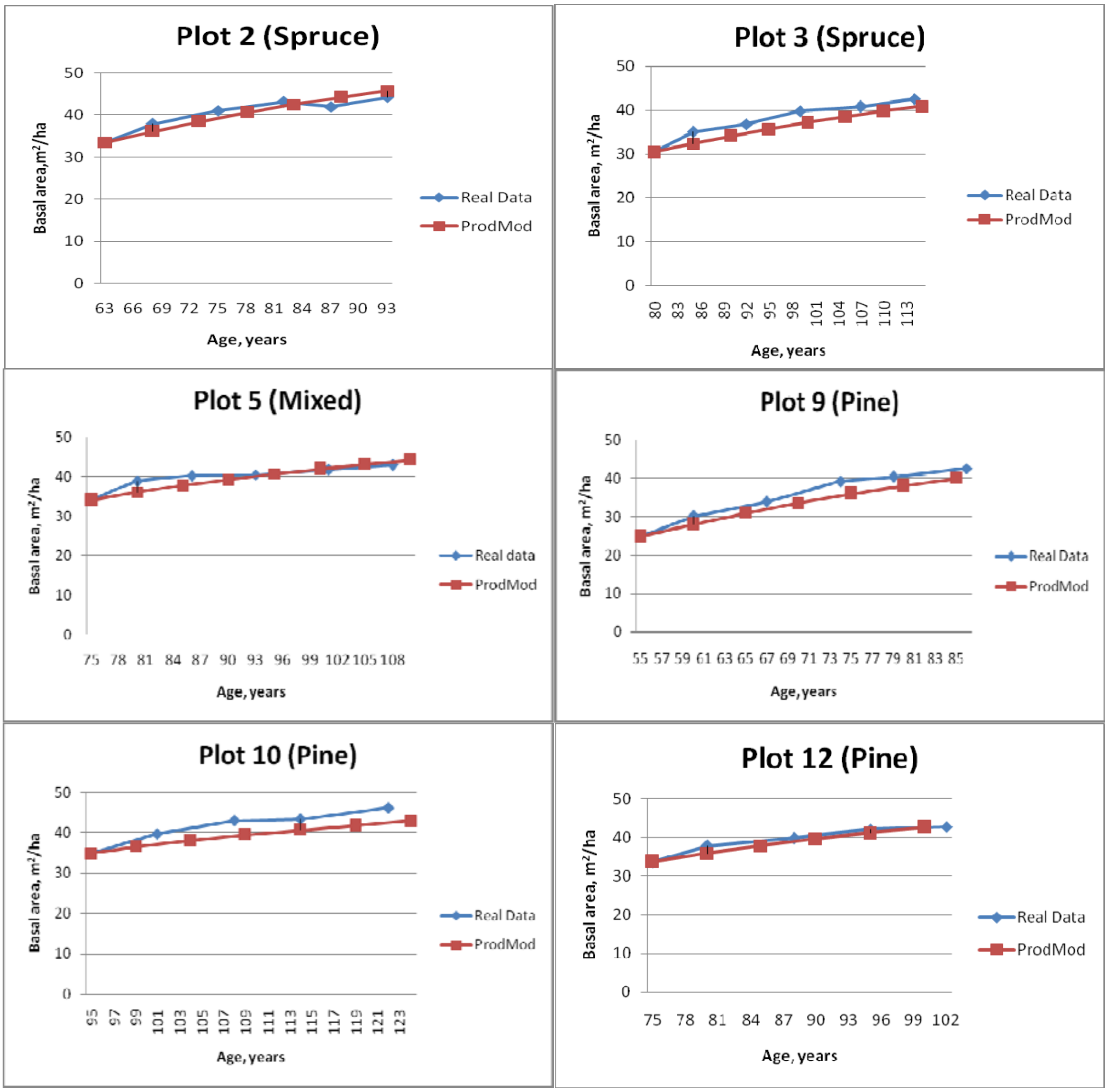

Figure 3 Comparison of simulated and observed development of basal area on plots 2,3,5,9,10,12.

Deviations of the ProdMod simulations from “real” data vary from 6 m^2/ha on plot 2 down to 1 m^2/ha on plot 10 with deviation of 2.5 m^2/ha on average The results consider whole simulation period). On plot 2 there is an empirical error or some disturbance (anthropogenic or natural, but not registered in data), which causes a decrease of basal area. Over the whole period of simulation the results do not differ much and there is no apparent trend of systematic over- or underestimation.

On the other plots (1, 7, 20a, 20b) the developments differ more dramatically (Figure 4).

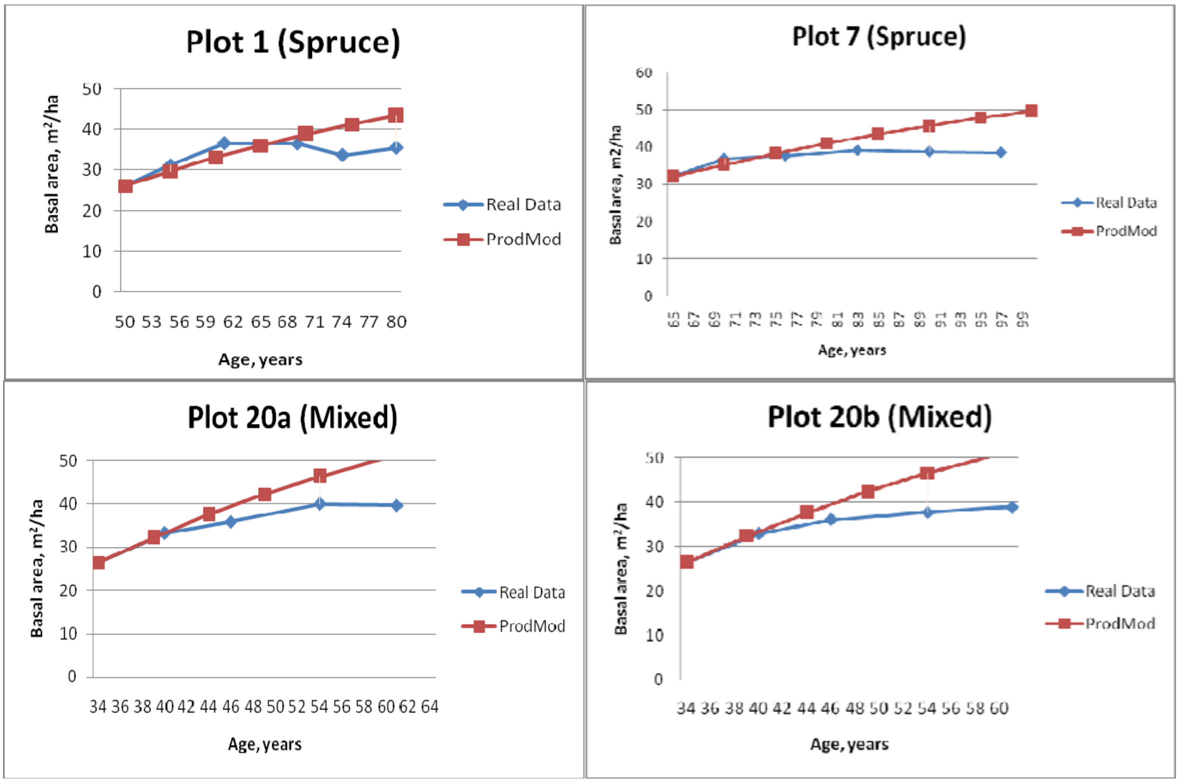

Figure 4 Comparison of simulated and observed development of basal area on plot 1, 7, 20a, 20b.

Deviations of ProdMod simulation from “real” data on these plots varies from 10 m^2/ha on plot 1 up to 15 m^2/ha on plot 20a. The deviation is 12.5 m^2/ha on average.

Over the whole simulation period the deviations in basal area development show a similar pattern: at the start of simulation (first few steps) the agreement is good, but after that the deviation starts to increase. In plot 1 there is most likely some bias in the empirical data. The situation is the same as described for plot 2 above.

Volume development

The deviations of volume development between the simulations and real data show the same pattern on plots № 2, 3, 5, 9, 10, 12 (Figure 5). These plots also have a good correlation of simulated and observed development of basal area.

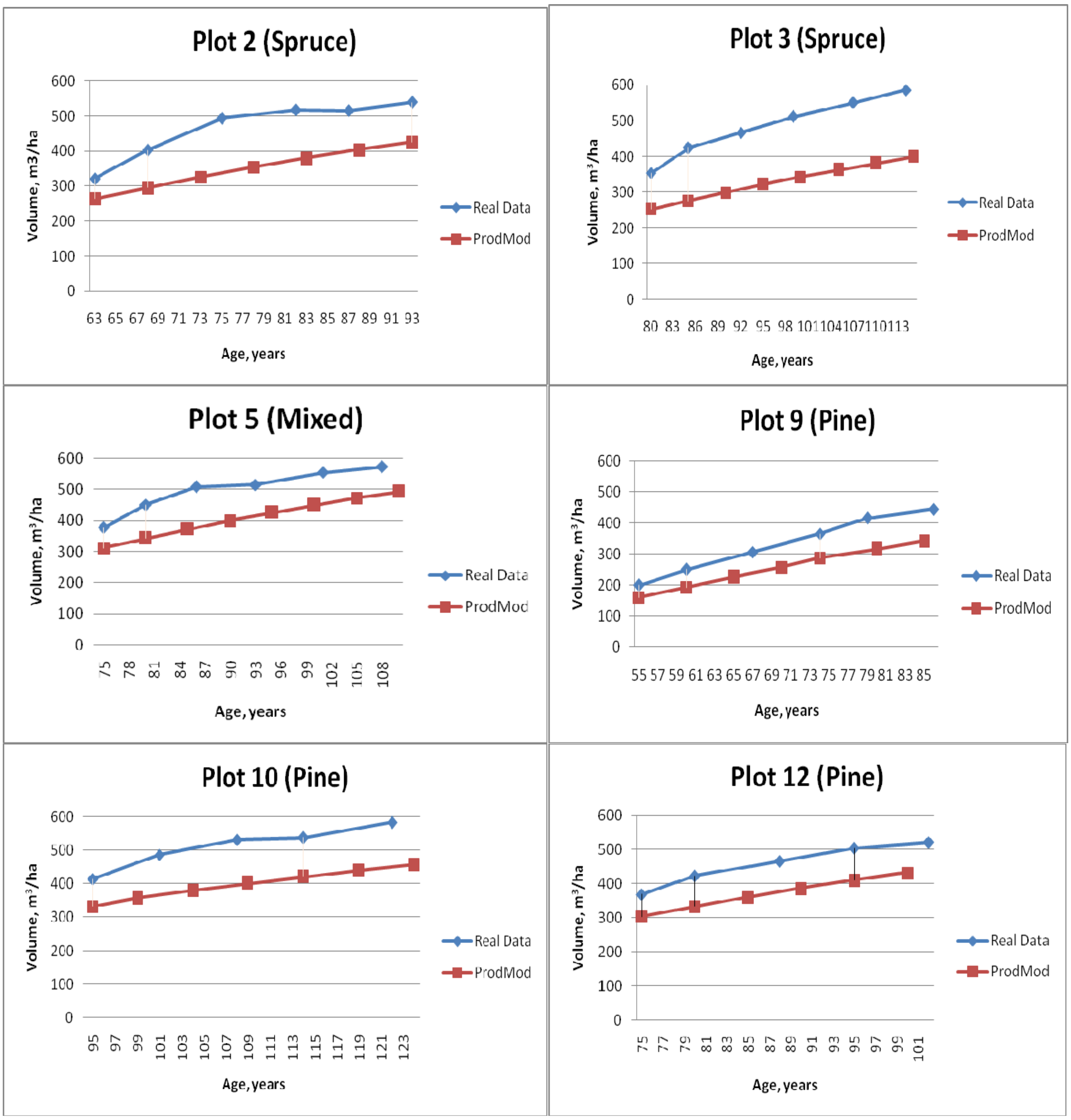

Figure 5 Comparison of volume development between simulation and empirical data on plots 2, 3, 5, 9, 10, 12.

Deviations of volume between ProdMod simulation and “real” data vary on these plots between 142 m^3/ha and 52 m^3/ha on plot 3. The deviation of ProdMod results from “real” data is 86 m^3/ha on average. The development curves are quite parallel so the difference is more or less constant over the studied periods.

On the remaining plots the deviations display different patterns (Figure 6).

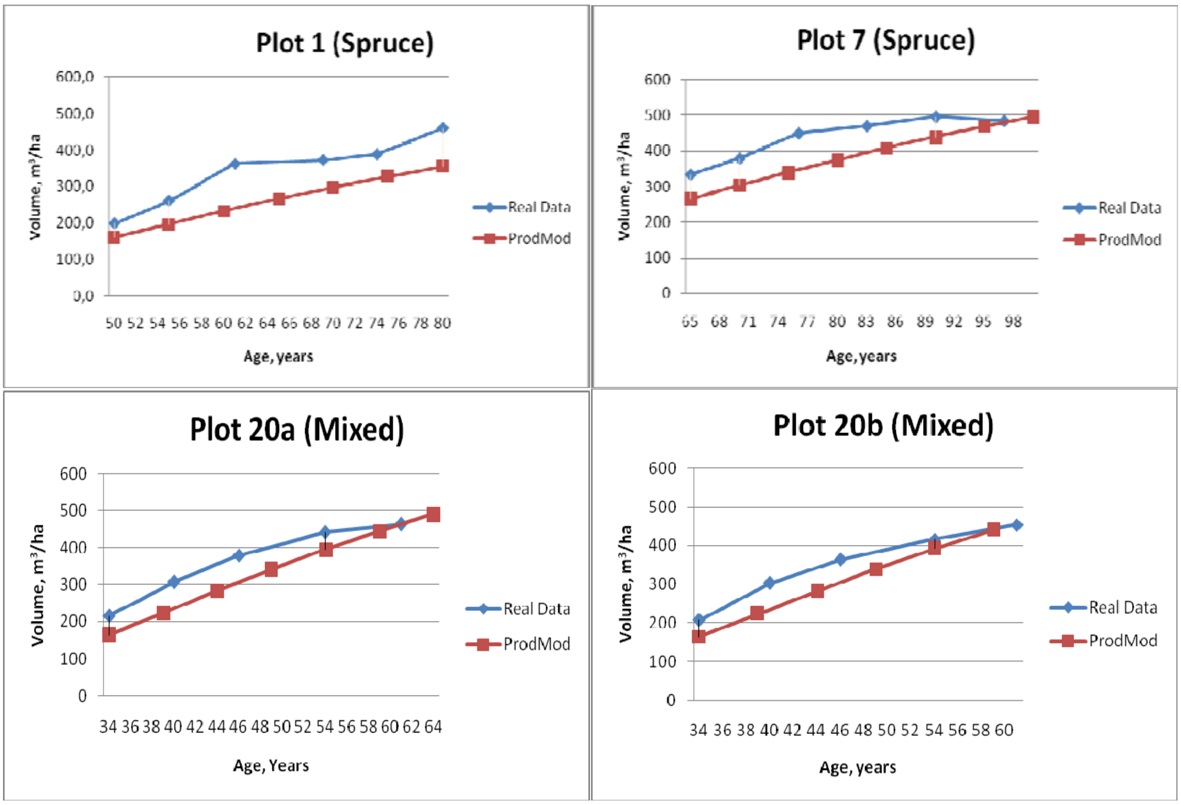

Figure 6. Comparison of simulated and observed volume development on plots 1, 7, 20a, 20b.

Deviations of volume in the last period between ProdMod simulations and the “real” data vary on these plots from 87 m^3/ha on plot 1 down to 21 m^3/ha on plot 20b. The deviation of ProdMod results from “real” data is 47 m^3/ha on average.

On plots 7, 20a, 20b the pattern deviations are similar to those discussed for the other set of plots, i.e. the difference between forecasts and the plot data are quite constant except for the last part of projection period, where the volume developments become more close to each other. Finally the volume of “real” data becomes lower than the volume estimated by ProdMod.

The pattern of the difference in the volume development on plot 1 differs from all other plots. When comparing the results from the basal area simulations and the volume simulations the general pattern is quite similar.

A summary of the forecasts by ProdMod and “real” data are presented in Table 8, where a comparison of basal area and volume at the last step of the ProdMod simulation is shown.

Table 8 Estimated basal area and volume at the last step of simulation, comparison with real data.

Dominant species	№ of plot	Basal area, m2/ha			Volume, m3/ha		
		Real	ProdMod	Difference	Real	ProdMod	Difference
Spruce	1	34	44	10	441	355	87
	2	40	46	6	482	426	57
	3	39	41	2	541	399	142
	7	37	49	12	467	496	29
Pine	9	42	40	2	440	343	97
	10	44	43	1	548	456	92
	12	41	43	2	505	432	73
Mixed	20a	38	53	15	439	490	51
	20b	37	50	13	432	453	21
	5	41	44	3	544	492	52

The plots with similar results of simulated and observed basal area development belongs to all categories of stands spruce, pine and mixed (Table 8). Pine stands shows in general a good correlation (Figure 3). Two of the spruce stands (Plot 2 and Plot 3) have also similar results, but two other plots show a big deviation. Two plots from mixed stands have a significant deviation between results and data. For mixed stands only Plot 5 shows good agreement (Figure 3).

Analysis of the age structure among the studied plots shows that age of the stand affect does not affect the results of basal area development in spruce and pine stands, but deviation of results in young mixed stands (plot 20a and 20b) is significantly higher in comparison with older one (plot 5).

Results from simulation of thinning programs

Simulation of thinning programs and calculation of NPV (Net Present Value) were made for all six programs specified in materials and methods. Total volume (after thinning and final felling) and results of the NPV calculations are presented in Figure 7, 8, 9 and Tables 9 to 13.Tables 9 to 13 present detailed information about each thinning program.

Table 9 Simulation of thinning programs and calculations of NPV for pure spruce stand. (Age - age of stand when thinning/final felling was done; Diameter - mean diameter at the time of harvesting; Volume – harvested volume; NPV – net present value; CAI – current annual increment; MAI – mean annual increment).

Stand	Program	Age	Diameter, cm	Volume, m^3/ha	NPV, €	Increment	
						CAI, m^3	MAI, m^3
Pure spruce	**4-25**	50	12	58	-40	9,0	4,4
		60	15	76	315	13,6	6,0
		70	18	86	269	12,2	6,9
		80	21	84	195	8,7	7,2
		100	25	337	768	6,0	7,0
			Total	**642**	**1507**		
	3-30	50	12	67	-44	9,0	4,4
		65	17	106	366	13,3	6,5
		80	20	116	269	9,8	7,2
		100	24	357	813	6,3	7,1
			Total	**645**	**1404**		
	2-45	50	12	101	-70	9,0	4,4
		80	21	206	520	11,1	7,2
		100	25	331	754	5,9	7,0
			Total	**639**	**1204**		
	1-70	50	12	156	-108	9,0	4,4
		100	25	326	742	5,9	5,3
			Total	**482**	**634**		
	No thinning	100	18	497	858	6,1	5,9
			Total	**497**	**858**		
	Synthesis	50	12	90	-59	9,0	4,4
	40-35-30	65	17	113	390	13,2	6,4
		80	21	97	225	8,3	6,8
		100	25	305	1132	5,6	6,6
			Total	**605**	**1688**		

Table 10 Simulation of thinning programs and calculation of NPV of pure pine stand.

Stand	Program	Age	Diameter, cm	Volume, m^3/ha	NPV, €	Increment	
						CAI, m^3	MAI, m^3
Pure pine	**4-25**	50	12	54	-92	9,9	4,4
		60	14	58	151	7,8	5,1
		70	17	58	101	6,5	5,3
		80	19	55	65	5,4	5,3
		100	23	229	308	4,3	5,2
			Total	**453**	**533**		
	3-30	50	12	64	-109	9,9	4,4
		65	16	75	120	7,4	5,2
		80	19	75	89	5,9	5,4
		100	22	241	324	4,5	5,2
			Total	**455**	**424**		
	2-45	50	12	96	-164	9,9	4,4
		80	19	128	151	6,3	5,2
		100	23	218	285	4,2	5,0
			Total	**442**	**272**		
	1-70	50	12	148	-253	9,9	4,4
		100	24	257	337	4,6	4,6
			Total	**405**	**84**		
	No thinning	100	20	481	384	6,6	6,3
			Total	**481**	**384**		
	Synthesis	50	12	54	-92	9,9	4,4
	25-35-35	65	15	93	148	7,7	5,3
		80	18	86	102	5,8	5,4
		100	22	222	299	4,3	5,2
			Total	**455**	**457**		

Table 11. Simulation of thinning programs and calculation of NPV of pure birch stand.

Stand	Program	Age	Diameter, cm	Volume, m^3/ha	NPV, €	Increment	
						CAI, m^3	MAI, m^3
Pure birch	**4-25**	40	10	39	-30	0,0	3,6
		50	13	54	274	9,9	5,0
		60	15	60	226	8,5	5,6
		70	17	62	192	7,7	6,0
		80	20	228	578	6,9	6,1
			Total	**442**	**1240**		
	3-30	40	10	43	-33	0,0	3,6
		55	14	75	345	9,2	5,3
		70	17	84	260	7,8	5,9
		80	19	237	601	6,9	6,1
			Total	**439**	**1173**		
	2-45	40	10	66	-40	0,0	3,6
		70	17	150	464	7,9	6,0
		80	20	222	563	6,8	6,1
			Total	**439**	**987**		
	1-70	40	10	103	-68	0,0	3,6
		100	22	294	746	7,3	5,5
			Total	**397**	**678**		
	No thinning	100	15	426	727	6,7	6,2
			Total	**426**	**727**		
	Synthesis	40	10	35	-28	0,0	3,6
	25-40-40	55	14	103	474	9,3	5,4
		70	17	104	322	7,7	5,9
		80	20	197	500	6,6	6,0
			Total	**439**	**1268**		

Table 12. Simulation of thinning programs and calculation of NPV of mixed stand of Spruce +Birch.

Stand	Program	Species	Age	Diameter, cm	Volume, m^3/ha	NPV, €	Increment	
							CAI, m^3	MAI, m^3
Mixed S+B	**4-25**	**S**	50	11,7	26	-18	4,0	1,9
		B	50	11,7	29	-20	4,4	2,2
		S	60	14,0	31	129	4,6	2,4
		B	60	13,5	31	117	3,8	2,5
		S	70	16,2	32	100	4,0	2,6
		B	70	15,3	15	46	3,3	2,6
		S	80	18,4	34	79	3,4	2,7
		B	80	17,1	118	299	3,2	2,9
		S	100	23,2	141	321	3,6	2,9
				Total	**455**	**1053**		
	3-30	**S**	50	12	28	-18	4,0	1,9
		B	50	12	32	-16	4,4	2,2
		S	65	15	40	138	4,6	2,5
		B	65	14	21	79	3,8	2,5
		S	80	18	46	107	3,8	2,7
		B	80	17	142	360	3,7	3,0
		S	100	24	118	268	3,1	2,5
				Total	**428**	**918**		
	2-45	**S**	50	12,0	50	-35	6,0	2,1
		B	50	11,6	51	-31	4,8	2,2
		S	80	18,6	42	106	4,4	2,8
		B	80	16,9	132	335	3,5	2,8
		S	100	23,1	194	442	4,6	3,1
				Total	**468**	**817**		
	1-70	**S**	50	12	81	-62	5,7	2,3
		B	50	12	76	-38	4,2	2,1
		B	80	17	71	180	2,0	2,2
		S	100	25	159	362	3,9	2,6
				Total	**386**	**442**		
	Nothing	**B**	80	16	217	550	4,7	3,4
		S	100	21	371	629	6,6	4,4
				Total	**588**	**1179**		
	Synthesis	**B 30**	50	12	33	-22	4,2	2,1
		S 30	65	16	65	224	6,8	3,3
		B 45	65	14	57	215	3,6	2,5
		S 30	80	19	69	160	5,5	3,7
		B 100	80	17	86	218	2,3	2,7
		S 100	100	23	220	501	5,0	3,9
				Total	**530**	**1296**		

Table 13. Simulation of thinning programs and calculation of NPV of mixed stand of Pine+Birch.

Stand	Program	Species	Age	Diameter, cm	Volume, m^3/ha	NPV, €	Increment	
							CAI, m^3	MAI, m^3
Mixed P+B	**4-25**	**P**	50	12	29	-54	5,2	2,3
		B	50	12	29	-20	4,6	2,2
		P	60	14	28	72	2,9	2,4
		B	60	14	31	117	3,8	2,5
		P	70	15	26	46	2,7	2,5
		B	70	15	15	46	3,3	2,6
		P	80	17	15	18	2,3	2,5
		B	80	17	119	296	3,2	2,9
		P	100	22	132	178	3,4	2,6
				Total	**424**	**699**		
	3-30	**P**	50	12	35	-65	5,2	2,3
		B	50	12	35	-23	4,6	2,2
		P	65	15	35	56	2,9	2,5
		B	65	14	21	79	3,7	2,6
		P	80	17	21	25	2,4	2,5
		B	80	17	142	360	3,7	3,0
		P	100	22	142	191	3,6	2,6
				Total	**431**	**623**		
	2-45	**P**	50	12	52	-89	5,2	2,3
		B	50	12	51	-31	4,6	2,2
		P	80	18	35	41	2,8	2,5
		B	80	17	134	340	3,5	2,8
		P	100	22	157	206	3,9	2,8
				Total	**429**	**467**		
	1-70	**P**	50	12	77	-136	5,2	2,3
		B	50	12	77	-44	4,6	2,2
		B	80	18	75	190	2,1	2,3
		P	100	26	158	207	3,8	2,6
				Total	**388**	**217**		
	No thining	**B**	80	17	201	370	4,2	3,2
		P	100	20	282	510	5,3	3,6
				Total	**484**	**880**		
	Synthesis	**B 30**	50	12	33	-22	4,6	2,2
		P 30	65	14	48	77	2,8	2,5
		B 45	65	14	58	220	3,6	2,5
		P 30	80	16	44	52	2,9	2,6
		B 100	80	17	90	228	2,4	2,7
		P 100	100	20	143	192	3,7	2,7
				Total	**416**	**747**		

Tables 9 to 13 present information about the outcomes of thinning programs for the different stand types. There is detail information about mean diameter, harvested volume and NPV for the each thinning operation or final felling. Total harvested volume and NPV are calculated for each thinning program.

NPV at the first thinning was negative for all stands, but the total NPV was positive. It varies between thinning programs and stand type. Harvested varies less than NPV for most of thinning programs. Figures 7, 8, 9 present information from Tables 9 to 13.

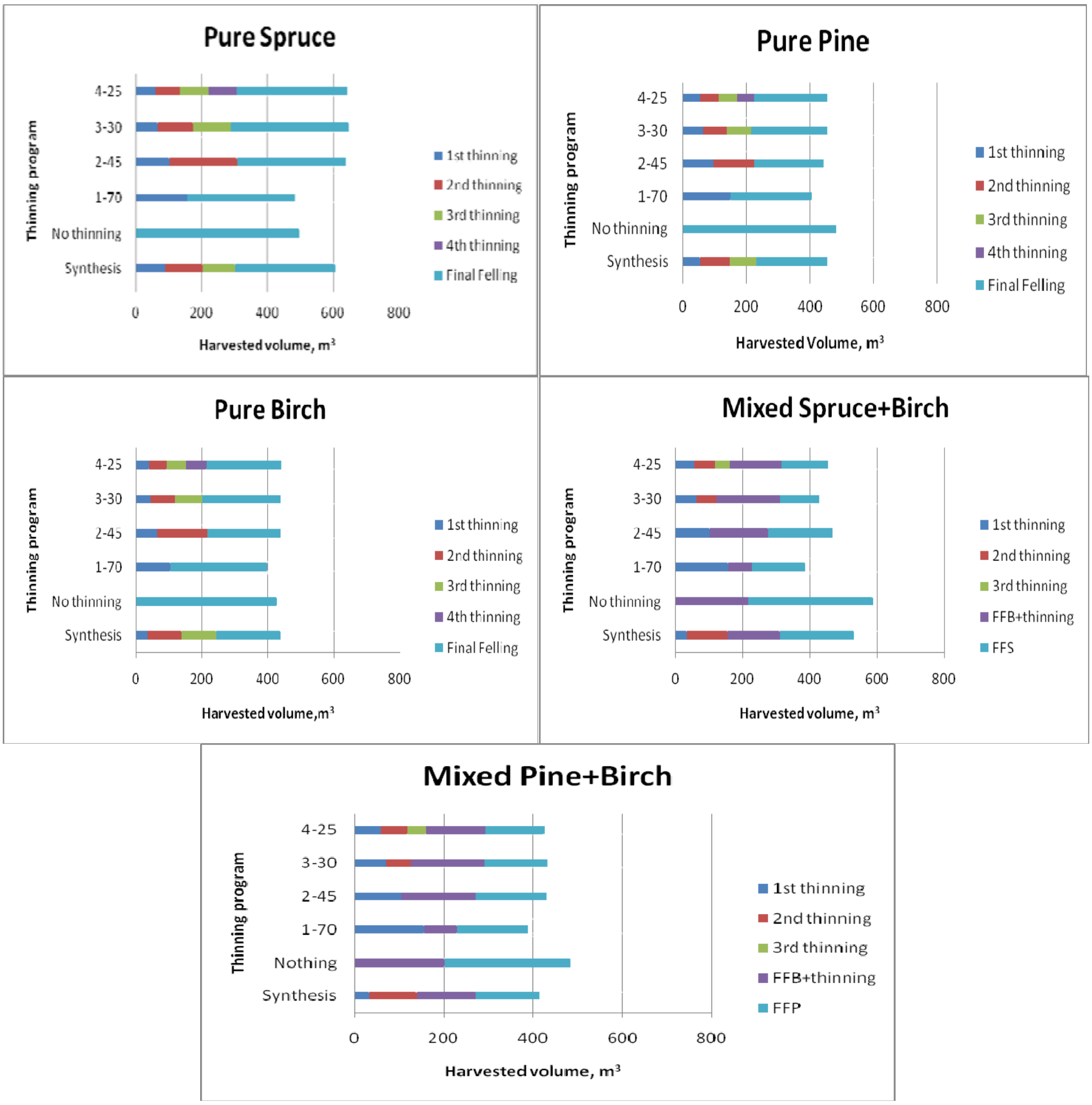

Figure 7 Comparison of estimated harvested volume from simulations of different thinning programs. 1st, 2nd, 3rd thinning is the number of commercial thinning. "FFB + thinning" means final felling of birch and thinning of coniferous species (spruce or pine). FFS and FFP is a final felling of spruce and pine respectively.

According to the Tables 5 to 9 and Figure 7 the thinning programs show the following results concerning harvested volume:

The biggest amount of harvested volume was found in the **No thinning** program (except pure spruce stand).

Thinning programs **4-25, 3-30, 2-45 and Synthesis** have similar results of harvested volume (the deviation is less than 8%).

The lowest harvested volume was found in **1-70**.

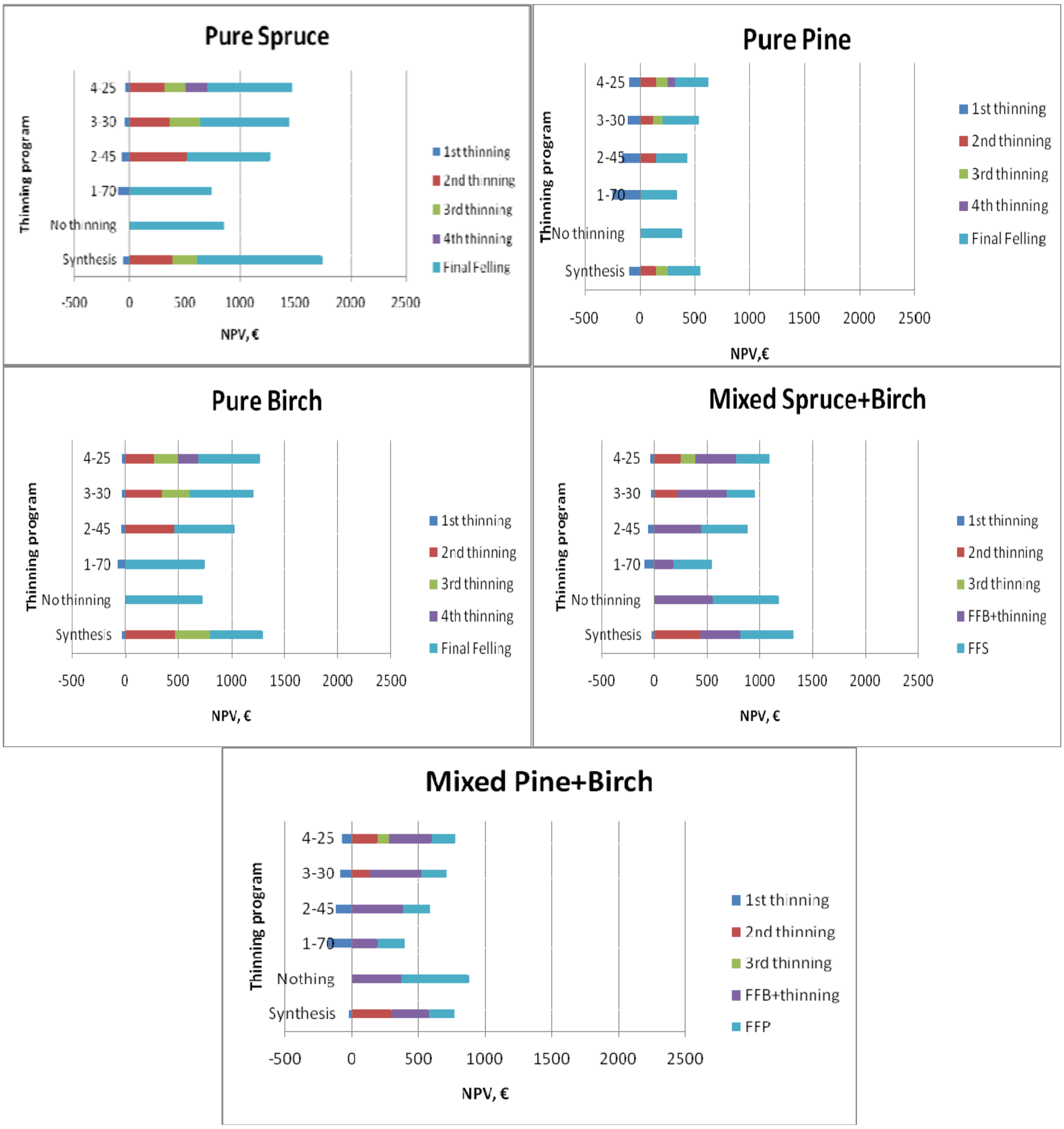

Figure 8 Comparison of NPV calculated for the different thinning programs.

According to Tables 9 to 13 and Figure 8 thinning programs show the following results concerning NPV:

The thinning program **Synthesis** shows in most cases the highest calculated NPV. **No thinning** shows high results in **mixed** stands, but has in **pure spruce** and **pure birch** stands the lowest NPV.

4-25, 3-30, 2-45 and **1-70** have in all stands a similar relation. **4-25** have the highest calculated NPV among them. **3-30** shows rather similar results to **4-25**, but is in all cases lower. Next is **2-45**, which a calculated NPV 10% to 50% lower than **3-30**

1-70 all the time shows the lowest NPV.

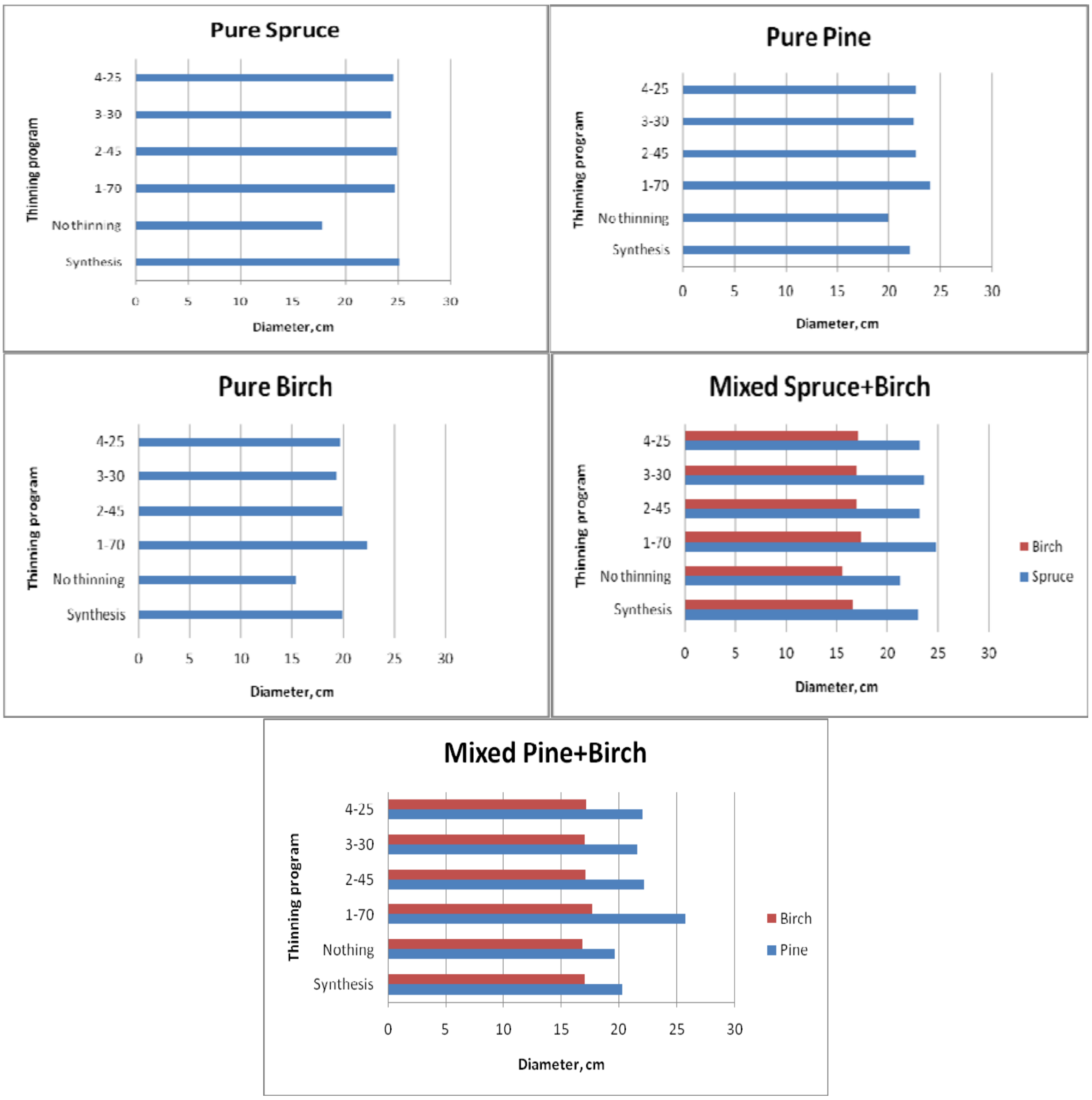

Figure 9 Mean diameter at the end of simulation of different thinning programs.

According to the tables 9 to 13 and Figure 9 the thinning programs show in summary the following results:

The fastest diameter development for spruce, pine and birch was found in program **1-70**.

4-25, 3-30, 2-45 and Synthesis show similar results of diameter development. Differences were small (maximum 2 cm).

No thinning in all cases showed the slowest diameter development. In pure birch and spruce stands the mean diameter of **No thinning** was 7 cm lower than in **1-70.**

NPV estimated for the same thinning programs but for Swedish conditions

The program “Assessment of net income” was used to estimate NPV for Swedish conditions (Figure 10):

Figure 10 NPV results for the different thinning programs calculated for Swedish conditions.

According to Figure 10 the calculation of NPV show the following results:

The highest calculate NPV was found in **4-25**. The biggest difference compared to the second highest NPV – 2120€, was found in pure spruce stand. The difference was considerable also for the other stand types.

Synthesis shows quite good results concerning NPV and is in the pure birch stand the highest compared to other programs.

No thinnig shows a quite low results in pure stands, rather similar to **1-70**, but in the mixed spruce+birch stand the calculated NPV is the highest.

1-70 has the lowest NPVin all cases. In pure birch stand it was 62% lower than highest calculated NPV.

3-30 and **2-45** shows rather similar results. The maximum deviation between them is 7%**,**in the mixed spruce+birch stand.

Discussion

Verification of the applicability ProdMod in the Leningrad region

Verification of ProdMod's applicability in the Leningrad region is one of the main goals of this investigation. The verification was made by comparing simulations with ProdMod to data from sample plots in the Leningrad region.

The comparisons show quite good agreement between the forecasts and the empirical data concerning development of basal area and volume. However in some cases there are noticeable deviations. There are obviously errors in the data which seriously affects the possibilities for comparisons. The basal area in some plots suddenly decreases without any explanation in documentation. However it must be caused by natural or anthropogenic disturbances.

One example is on plot 2 (Figure 3) where basal area decreases in one period without any explanations. Almost the same situation was found on plot 1 (Figure 4). There is another pattern of deviation on plots 7, 20a, 20b (Figure 4). Plots 20a and 20b represent a younger stands and plot 7 presents an almost mature stand. The phenomena that a stable basal area level is reached is typical for old stands, but not for younger stands like in plots 7, 20a, 20b.

One possible reason for deviation between simulations and data could be different methods of assessing site index in Russia and Sweden. In Russia SI is assessed in five classes (I to V). Site Index is determined based on average height, age and forest type. In Sweden SI is top height at 100 years for the particular specie. Possible errors can appear because of translation of Russian SI into Swedish SI.

The comparison of volume development shows almost the same pattern as in the case of basal area development. On plots where deviation in basal area is small there is a constant difference between estimated and observed volume. On other plots deviations vary significantly in the same way as basal area.

One reason for the deviations in volume is different ways of assessing volume in Russia and Sweden. In Russia there are two types of volume: merchantable volume and stand volume. Merchantable volume includes all what has a value on the market (firewood, pulpwood and sawn timber). Stand volume includes merchantable volume plus branches and the top. The researchers, who established and inventoried the sample plots in this study, used stand volume. In Sweden stand volume does not include branches. Therefore the estimations by ProdMod should underestimate the volume found in the empirical data.

One way to investigate this theory is estimate of biomass with ProdMod. The biomass of living and dead branches is compared to biomass above stump. Simulations showed that the share of branches on average is 20% on average of the biomass above stump (in our investigation underestimation of volume in average was 26%).

Systematical errors can also appear due to that a certain altitude can indicate different growing conditions between Leningrad region and Sweden (different climate conditions). Different definitions of vegetation type and soil conditions could also lead to deviations.

Generally, the forecast of basal area development seems to be reliable; ProdMod predicts stem volume. However merchantable volume is better for economic evaluation since it can be used in economical assessment without any corrections.

My judgment is that the applicability of ProdMod is acceptable for future investigations of thinning programs in the Leningrad Region. It is an interesting challenge to use this model to analyze thinning programs in North-West Russia.

Results from thinning program simulations

The simulations includes six different thinning programs applied in stands with different tree species composition Harvested volume, total production, diameter development and estimated NPV is compared. The aim of this study is to suggest thinning programs, which can be successful, from economic point of view and adapted to the conditions of North-West Russia. Each thinning program is discussed below.

Harvested volume:

No thinning are in most cases an effective program considering harvested volume (Figure 7). **1-70** has the lowest harvested volume in comparison with the other programs. Comparison of the highest and the lowest harvested volume is present in Figure 11.

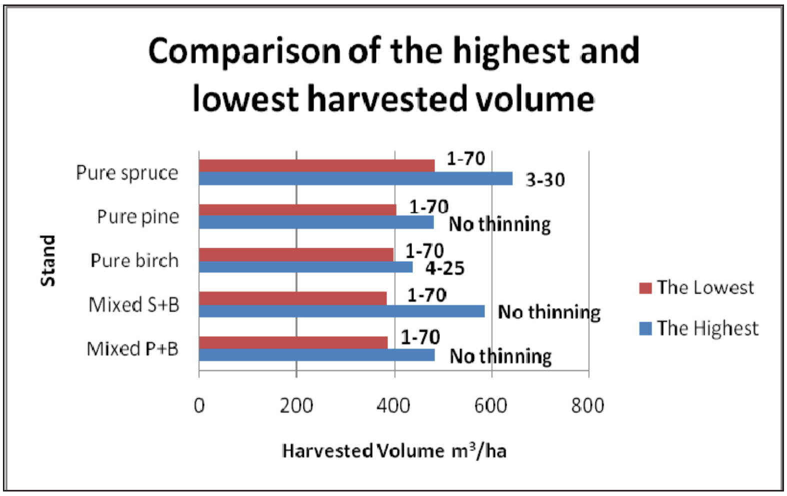

Figure 11 Comparison of the highest and the lowest harvested volumes.

The difference between the highest harvested volumes from the lowest varies for the different stands from 10% to 34% and is 21% on average (Figure 11). The highest harvested volume is in the pure spruce stand with program **3-30**, the lowest harvested volume is in spruce/birch stand, with **1-70**.

No thinning most of the time has a highest harvested volume, it generally correspond to common knowledge that volume production decrease by any of the treatments (Pape, R 1999).

Economic outcomes:

Synthesis shows for most of stand types the highest NPV (Figure 8). **4-25** and **3-30** show medium results. In pure pine stand **4-25** have the highest NPV, more than 6 times higher compared to the lowest NPV, which calculated for **1-70** (Tables 9 - 13). **No thinning** has the lowest NPV in pure stands, but has one of the highest NPVs in mixed stands.

The **2-45** program shows next-to-last result of NPV, due to the intensive 1st commercial thinning. The **1-70** has the lowest harvested volume in comparison with the other programs and also the lowest calculated NPV (Figure 8). The first thinning is very detrimental. This program should be unfavorable from an economic point of view. Comparison of the highest and the lowest results of calculated NPVs presented in Figure 12.

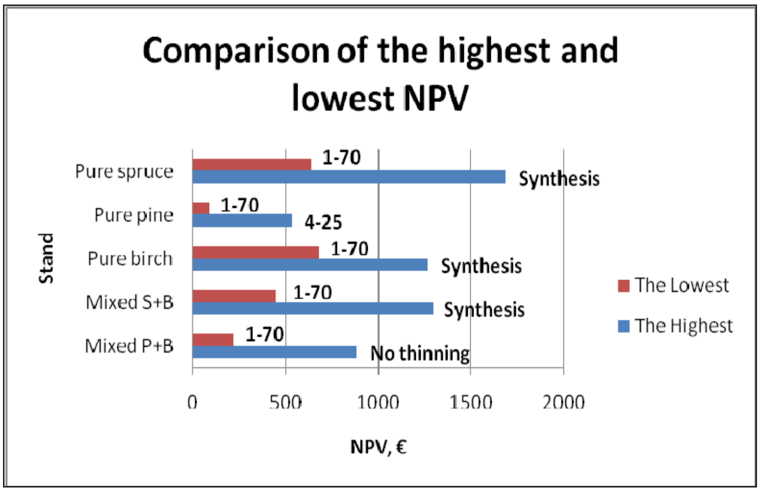

Figure 12 Comparison of the highest and the lowest NPV.

Pure spruce stand has the highest NPV compared to the other stand types (Figure 12). Pure pine stand has the lowest NPV, because the specie has highest stumpage fee and low price for pulp and sawn timber, compared to spruce and birch. The highest NPV in mixed spruce/birch is lower than NPV result for pure spruce stand and higher than the NPV for pure birch stand (Figure 12).

Diameter development:

1-70 is the program which gives the fastest diameter development, more than 15 % faster compared to **4-25** for pine in the mixed pine/birch stand (Figure 9). One heavy thinning promotes left trees to grow more rapidly in comparison with the other programs. **No thinning** shows the slowest diameter development, due to the highest density all over the rotation. The other programs show quite similar results of diameter development.

Comparison of the fastest and slowest diameter developments presented is in Figure 13 (for mixed stand present diameter development of coniferous species).

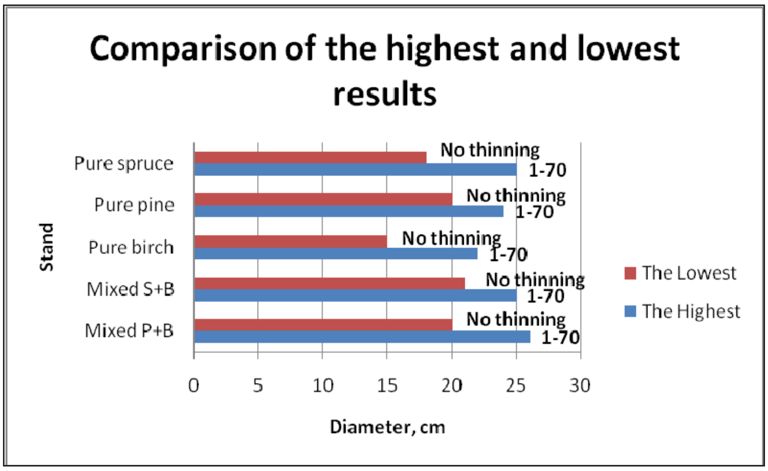

Figure 13 Comparison of the highest and the lowest results of diameter development.

The diameter development among in the different stand types differ. The fastest development is on average 21% faster than the slowest (Figure 13).

The general distribution of results in different stands concerning harvested volume and NPV is rather similar (Figures 11, 12). At the same time the highest result in harvested volume doesn't provide the highest result of NPV and vice versa. There is a quite obvious range of successful, intermediate and inappropriate thinning programs (Figures 7, 8, 9).

The most profitable thinning program is **Synthesis** (Figure 8), which is an effort to create a successful (from economical point of view) thinning program for each stand type. This program contains 3 thinnings with different intensities and timing, differentiated for each stand type. Based on the results discussed above it is obvious that for each stand type successful programs should be individual adapted, with specific intensities and frequencies.

Comparison of studies thinning programs with Russian thinning guides

Comparison of the studied thinning programs was made with Russian thinning guides. These guides are created in cooperation with the Swedish National Board of Forestry, Northwest Forest Inventory Enterprise, Saint-Petersburg Forestry Research Institute and the team of Pskov Model Forest Project (Romanyuk et al, 2005). Results of comparison are presented in Figure 14.Different guides are used for different site indices, forest types and tree species.

To work with the thinning guides the following variables are required: average height, age, basal area and stocking. SI is determined based on average height and age. In our case SI III was chosen, because it is the average SI in the Leningrad region.

According to the instruction for thinning guide the first thinning should be done with high intensity and reduce basal area down to the lowest allowable level. The next should not be stronger than 0.7 of related basal area for particular site index. The main aim of the Russian thinning guide is to promote a highly valuable stand by the time of final felling. In economical terms the first heavy thinning leads to big losses and the following thinning give only small incomes. From economic point of view this schedule leads to an insignificant income from thinning and the main income is expected from the final felling.

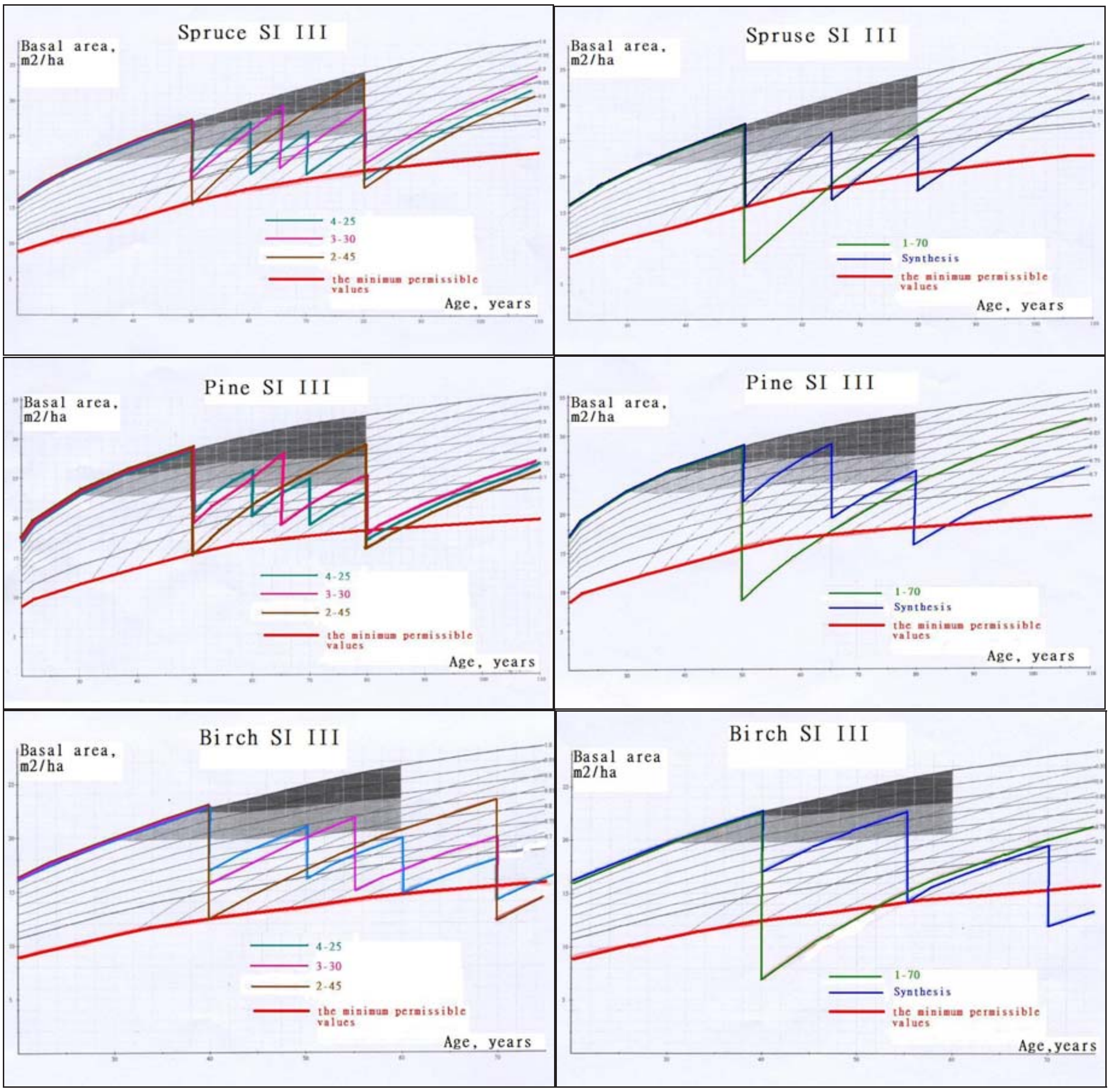

Figure 14. Comparison of thinning programs with Russian thinning guides.

4-25, 3-30 represent thinning programs of intensive forest management. In terms of Russian forest guide these programs are allowable according to Russian forest legislation, but thinning intensity of last operation should be lower (Figure 14). For North-West Russia **4-25** is hard to implement, because of a not well developed road net, old technologies of harvesting and big forest area, but implementation of **3-30** seems more realistic.

Considering Russian forest guide **2-45** is generally allowed, but with some changes in intensity like **4-25** and **3-30**.It is a typical thinning program in North-West Russia, so it is rather realistic for those conditions, but not as profitable as other programs (Figure 8).

1-70 isn't an allowable thinning program according to the Russian forest guide (Figure 14). The first heavy thinning removing 70% of the basal area doesn't comply with the Russian thinning rules. The basal area left after thinning is significantly lower than the minimum required. It program is easy to implement, but at the same time there is the highest risk of wind thrown, fire damages and infections due to the low number of remaining trees.

No thinning is a typical program for extensive forest management. In North-West Russia there is quite big area non-touched by human activity, so this is wide spread thinning program. It is suitable for the regions with huge forest area, but nowadays this is not suitable for North-West Russia due to depletion of forest resources.

According to the Russian forest guide **Synthesis** is an inacceptable thinning program, due to the high intensity in the second and third thinning operations (Figure 14). This program belongs to intensive forest management and leads to sufficient control of stand development, but thinning intensity should be decreased due to Russian thinning rules. **Synthesis** was found to be the most profitable program in this study (Table 9-13) and in conditions of North-West Russia its implementation seems rather realistic.

The investigation is based on average site index in Russia, representing yield class, which is low productive. For higher site index basal area growth after thinning is faster and more intensive thinning operation seems more desirable.

Recommendations:

1. Changes in intensities to increase income from thinning;

2. Invest in pre-commercial thinning;

3. Flexibility for different SI.

Comparison of NPV results of Sweden and Russia

NPVs calculated for Swedish conditions were rather similar to Russians NPVs in case of ranking. There are changes in ranking for some results of particular thinning programs, but general trends are rather similar. Comparisons of Swedish and Russian NPVs are presented in Figure 15.

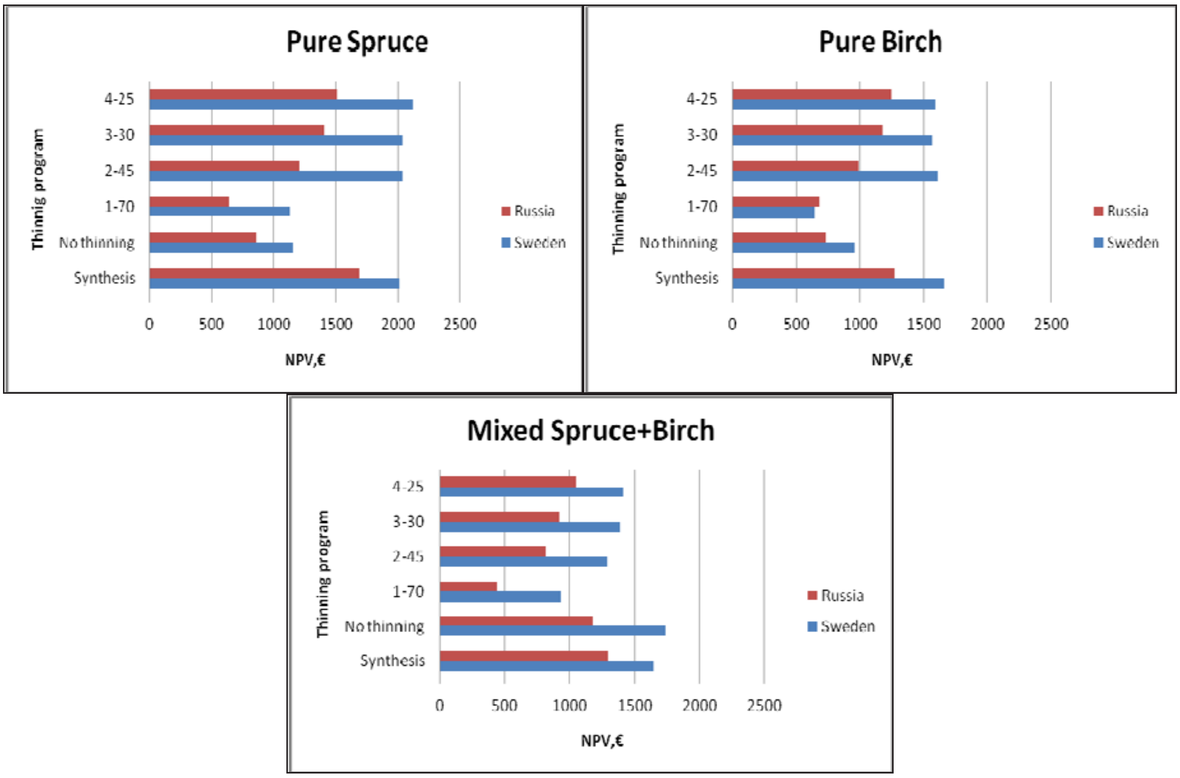

Figure 15. Comparison of calculated NPV in Sweden and Russia for the different thinning programs.

Generally the estimations for Swedish conditions show a higher NPV in all stand types and for all programs (one exception is the pure birch stand with program 1-70). On average the difference is 31% in pure spruce stands, 21% in pure birch stands and 33% in mixed spruce/birch stands (Figures 10, 15).

The net income from final felling makes the biggest contribution to NPVs; some thinning operations also give essential contribution, but in general much less. For Swedish conditions the first thinning in most cases gives a small income in distinction from Russian conditions, were there in all cases is loss.

Difference between Russia and Sweden arises because of different efficiency of logging operations, difference in forest road net, price for timber, differences in logistic features and stumpage fees (Figure 15). These circumstances directly affect the net income.

Practical application of ProdMod and conclusions

Results of the investigation show that ProdMod is a quite reliable and useful computer forest growth simulator. It hasn't been falsified that ProdMod cannot be applied in the Leningrad region. Therefore it has potential use in forest planning, updating of materials of forest inventory and calculation of possible harvested volumes

Forest is a complicated system, which includes different subsystems (Melechov, 1980), so it is quite hard to forecast the development. Based on long term observations computer programs can predict stand development with reasonable accuracy. Of course, no computer program can reflect the development perfectly, so there is still room for improvements. For example, the Forest Management Planning Package designed by the Swedish University of Agricultural science is an interesting example of a combination of forest inventory, forecasts and optimization methods, which has had an effect on Swedish forestry, but authors continue to develop this system in response to experiences and needs (Jonnsson et al, 1993). A new planning system has recently been launched. - HEUREKA (Lamas et al, 2003)

There is no universal thinning program for each stand type, since it among other things depends of the owners goals. Each program has pros and cons – one program gives the highest harvested volume, another - the fastest diameter development, a third - the highest NPV, a fourth - more valuable assortments, a fifth – is easy to implement etc. There is no program, which combines only the best results; each program has its week side (Figures 7, 8, 9).

There are lots of factors affecting forest management: site index, tree species composition, density of road net, logging technologies, spatial allocation of forest stands, and allowable age of cutting. Comparison of NPV calculated for Russia and Sweden shows that the revenue from thinning operations can differ significantly.

There is a huge amount of different factors affecting the outline of the thinning program and decision makers should pay attention to all of them; ignoring one factor can lead to significant losses in efficiency. Modern resource management is concerned with the economics of sustainable use of biological resources; it means that the main goal of forest management is to find a compromise between net present value (basic economic principles) and sustainable development (Jonnsson et al, 1993). Further research can make relations between parameters of thinning and stand composition more clear, making it possible to suggest improvements for computer.

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2. *Government of Leningrad region*: www.lenobl.ru

3. Greenpeace Russia (Forest): www.forestforum.ru

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